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National Assessments of Wildlife and Fish: A Technical Framework

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National Assessments of Wildlife and Fish: A Technical Framework

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Abstract

A national assessment of wildlife and fish can be accomplished by completing three analytical components of the Forest and Rangeland Renewable Resources Planning Act: providing a statement of historical and current land, wildlife, and fish population and habitat production capability; projecting future production and consumption; and identifying opportunities for improving the future renewable resource situation regarding wildlife and fish and their habitats.

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Thomas W. Hoekstra and John G. Hof

Background

National assessments of renewable resources, including wildlife and fish, are required by federal law to describe the past, present, and future status of renewable natural resources. Assessments should satisfy not only the legal requirement, but also two other objectives: to determine the social, economic, and environmental implications of trends in production and consumption of renewable natural resources; and to present the findings in a form that would be of use to public land management agencies in program development. This report interprets the law so as to suggest a technical framework to use as a guide in accomplishing a national assessment of wildlife and fish.

The USDA Forest Service, responding to the requirements of the Forest and Rangeland Renewable Resources Planning Act of 1974 (RPA)[2] conducted national assessments in 1975, 1980, and 1984 (USDA Forest Service 1977, 1980, 1984). Other national evaluations of the wildlife and fish situations have been conducted to address specific issues or concerns about the resource. A National Appraisal of Fish and Wildlife Habitat was conducted by the USDA Soil Conservation Service (1980) in response to the Soil and Water Resources Conservation Act of 1977 (RCA).[3] Other evaluations include the National Academy of Sciences (1970) report, "Land Use and Wildlife Resources," and the Council on Environmental Quality (1978) report of a national symposium, "Wildlife and America."

Additional perspective on the definition, components, difficulties, and successes of conducting a national assessment have come from several other sources: (a) the procedures used to conduct the 1980 RPA Assessment of Wildlife and Fish (Schweitzer and Cushwa 1978); (b) a progress report (Schweitzer et al. 1978); (c) a preliminary evaluation of the 1980 database (Hoekstra et al. 1979); (d) lessons learned in carrying out the National RPA Assessment of Wildlife and Fish (Schweitzer et al. 1980); (e) a report on the role of assessments in monitoring (Hoekstra et al. 1983); and (f) the recommended data base for use in 1989 (Hoekstra et al. 1983).

A national assessment of wildlife and fish can be accomplished by completing three technical renewable resource oriented components of the RPA: (1) describe and quantify the historical and current status of land area, wildlife and fish populations, and habitat production capability, (2) project future production and consumption, and (3) identify opportunities for improving the future renewable resource situation regarding wildlife and fish and their habitats.

[2] *Public Law 94-378, 88 stat. 476.*
[3] *Public Law 95-192, 91 stat. 1407.*

Past RPA assessments accomplished some aspects of components 1 and 2 but did not effectively address component 3. To some extent the deficiencies of the RPA and RCA assessments resulted from limited experience in incorporating wildlife and fish resources into production, consumption, and alternative opportunity analyses. Deficiencies continue to exist in available data and analytical techniques for accomplishing these components.

Historical and Current Status

This component most closely follows the conventional perception of how to describe the status of wildlife and fish resources. National and regional summaries of land, resource stocks, and production capabilities have been, and can continue to be, compiled from inventory data files. The continuous forest inventory of the USDA Forest Service (1985) and the national resource inventory of the USDA Soil Conservation Service (1982) are the principal sources of habitat information. State wildlife agencies are the main sources of population and harvest information. The USDI Fish and Wildlife Service is the source of information on migratory and threatened and endangered species populations. However, as Hoekstra et al. (1980) have reported, given the above sources, consistent data for a nationwide assessment of wildlife and fish still exist only in part, even after two RPA Assessments and one RCA Appraisal. Ideally, such data files would include estimates of wildlife and fish species populations, habitat capability, and other renewable resource quantities associated with the same land areas.

A standardized basis for compilation of wildlife and fish habitat information is proposed in table 1. For use in national assessments, land area should be described by resource characteristics and production capability at the county level in 5-year intervals. Ideally, spatial relationships of different ecological conditions should be defined for resources such as wildlife and fish that are dependent upon landscape patterns. Measures of the relative quantities of different ecological conditions as well as their size, shape, and distribution are needed. Descriptions of land area by land use and land cover can be derived for some areas of the nation through the U.S. Geological Survey land use and land cover inventory (Anderson et al. 1976). To the extent that such inventory information is available and compatible with the Forest Service and Soil Conservation Service inventories, it will improve national assessment descriptions of the wildlife and fish habitat situation. Chalk et al. (1985) have recommended a framework for integrating information from Forest Service and Soil Conservation Service multiresource inven-

Table 1.—Information on the nation's land and water base needed for a wildilfe and fish assessment.

Time Interval	
5-Year or Annual	
Geographic Identification	
State	
County and USGS Hydrologic Cataloging Unit	
Type of Information	
	Units
Land Area described by:	Acres
Ownership	
Land Use	
Vegetation Cover Type	
Vegetation Condition Class	
Vegetation Structure Class	
Soil Family	
Current Habitat Capability	
Water Area described by:	Acres
Water System Type	
Water Temperature	
Water Turbidity	
Water Toxicity	
Water Flow	
Water Nutrients	
Geomorphologic Factors	

tories for use in national assessments and appraisals of wildlife and fish.

Current actual and potential habitat capability information in table 1 describes land capability in terms of productivity and condition of wildlife and fish resource stock. Habitat capability estimates are calculated from information on the current quantities of habitat, populations, and land management actions by such methods as multivariate statistical models (Capen 1981), pattern recognition models (Williams et al. 1977), habitat evaluation procedures (U.S. Department of Interior, Fish and Wildlife Service 1980), and wildlife habitat relationships (Nelson and Salwasser 1982). Current habitat capability is defined by the current population level of a species in its current habitat on a particular land unit. Potential wildlife and fish habitat capability is defined by the population level of a species that the habitat should be capable of producing under a specific land management action(s) on a particular land unit for a specified time period. Ideally, current and potential habitat capability would be calculated as the estimated number of animals produced per unit of land (e.g., kg/ha). The need to consider interspecific interactions (e.g., competition or production) is recognized, and such interactions are considered to be implicitly accounted for in current and potential habitat capability (Flather and Hoekstra, in press).

A standardized basis for compilation of information on wildlife and fish populations, harvest, and consumptive use is proposed in table 2. An information base for both habitat and populations (size and use) on a common geographic basis is essential for both compilation and predictive purposes. For most species, indexes of population and/or numbers of animals harvested serve as surrogate measures for the more desirable population size estimates as these are frequently the only measures available. Because state wildlife and fish agencies typically estimate size and use annually, it is expedient to develop the RPA information base in that manner. The information in tables 1 and 2 is useful for describing the current or historical situation. It tells where we are and how we might have gotten there.

Consumption and Inventory Projections

The second component, which calls for a projection of the consumption and inventories of renewable resources into the future, is a substantial extension beyond the first.

Consumption Projections

Over the years, a number of studies have attempted to project recreation consumption levels (including recreational consumption of wildlife and fish) for specific regions and the entire nation (e.g., Kalter and Gosse 1969, Cichetti et al. 1969, Adams et al. 1973, Wegert 1979, Hof and Kaiser 1983). It is generally agreed these are not true demand projections in the economic sense. They are projections of actual consumption levels that are affected by both supply and demand factors.

For resources provided through a market, a traditional competitive market structure would be appropriate for projecting consumption. In a competitive market, pricing serves to bring demand and supply into an "equilibrium." An excellent example of this sort of projection model is the Timber Assessment Market Model (Adams and Haynes 1980).

In general, consumption of wildlife and fish (especially recreational consumption) is not governed by a market, so a market "equilibrium" is probably not an appropriate concept for such projections. For such nonmarket goods, Hof and Kaiser (1983) recommend the following consumption function for use in projections:

$$Q_c = F(P,X_i,Q_p) \qquad [1]$$

where

Q_c = the quantity of wildlife and fish resources actually consumed

P = a price surrogate, e.g., travel costs or time costs

X_i = the traditional "demand shifters," such as, population (human), income, and age

Q_p = the quantity provided (wildlife and fish resources available).

They discuss the Qc as a "disequilibrium" between supply and demand factors. In order to project Q_c, the function F must first be estimated (generally regressed) based on historic (time series) or cross-sectional data. Then, by substituting projected levels of P, X_i, and Q_p, a projected level of Q_c can be calculated. This, of course, assumes that the function F is unchanging throughout

Table 2.—Information on the nation's wildlife and fish populations and their use needed for a wildlife and fish assessment.

Time Interval

Annual

Geographic Identification

State
Wildlife and Fish Administrative Region (Multicounty)
County and USGS Hydrologic Cataloging Unit

Type of Information

	Units
Species Population Size	No./Area or Index
Species Harvest	No./Area
Consumptive Users (by Species)	No. and Effort/Area

the projection time period. It should also be noted that little is gained if projection of the P, X_i, and Q_p variables is, in fact, as difficult as projecting the Q_c in the first place. A simply alternative is to utilize the time trend of Q_c, or to simply regress Q_c against population levels and then apply population projections alone.

Two important points need to be stressed concerning consumption projections. First, such projections are, in essence, only extrapolations of past trends. They do not necessarily represent a desirable level of consumption. Thus, it is not appropriate to project consumption and then treat it as a "target" level of "demand" to be met. As an extreme analogy, this would be like predicting the eminent extinction of a particular species, such as blue whales, and then working diligently to promote that prediction. Wildlife and fish consumption projections should only be used for predicting large-scale overuse of particular wildlife and fish resources.

Second, strong evidence is available (Kalter and Gosse 1969, Cichetti et al. 1969, Hof and Kaiser 1983) to suggest that the Q_p variable in equation [1] is very important in determining the Q_c. This implies that if wildlife and fish resource production is increased in an attempt to "meet" a given set of consumption projections (in the hope of reducing overuse), then this alone will probably result in consumption levels higher than would have occurred otherwise. This is hardly a shocking conclusion; if resource "supplies" are in any way restricting or inhibiting consumption, then it is obvious that increasing "supplies" will cause increased consumption. However, it is easy to forget this logic when attempting to obviate large-scale overuse problems.

Inventory Projections

Current and historical inventories of wildlife and fish populations and their habitats provide information on past trends in resource quantities. Analysis of factors such as land use that are correlated with these trends can assist in making projections of future inventories. Such projections are generally based on three classes of assumptions: (1) ecological assumptions concerning land capability, population biology, and management actions; (2) economic assumptions on resource markets, resource harvests, income, and employment; and (3) social structure assumptions defining institutional variables.

For resources provided through the public sector, as from the National Forests or lands administered by the Bureau of Land Management, estimates of future inventories can be obtained from land and resource management planning activities. This is generally not true for private lands. To be useful, estimates of future resource inventories on private lands must account for differences in ownership objectives.

Models based on the set of ecological assumptions have been developed to project future wildlife and fish populations based on current numbers, sex and age ratios, natality, harvest, and mortality rates. Other models have projected future wildlife and fish populations based on relationships to habitat (Hawkes et al. 1983). Ideally, population inventory projections would be made using both population and habitat parameters; however, inadequate data and analytical tools impose severe limitations.

Prediction of wildlife and fish populations based on population size, structure, and dynamics is difficult, and few techniques exist that can be applied to produce accurate and precise information, except for use in very local situations. Many species do not lend themselves easily to direct population estimation due to mobility and behavioral characteristics (Miller 1984). Potential population estimates based on size, structure, and dynamic attributes of species populations and some assumed environmental conditions lack an explicitly stated relationship to current habitats and, therefore, are difficult to relate to land management activities.

Predictions of wildlife and fish populations can be classified as indirect or direct, depending upon the kind of wildlife habitat relationships model used. In the case of indirect population estimates, the habitat relationship models estimate the potential suitability of the habitat to support a species population. Population levels are not a product of the model and suitability indexes cannot be reliably or consistently converted to population levels. The more direct approach uses multivariate statistical methods (Capen 1981). In this approach, measured populations are correlated with inventoried environmental variables to establish the relationship between habitat and populations (Kitchings and Klopatek 1982)[4]. The multivariate statistical models developed by Kitchings and Klopatek are a prototype for more detailed models being developed for the 1989 Assessment.

The 1989 assessment models are based on the land and water base descriptions in table 1 and the population information in table 2. Counties are the sample unit, but results are reported by ecological and/or Forest Service administrative regions (multistate). Future populations can be predicted based on different scenarios about changes in the correlated land and water base

[4]*Kitchings, Thomas, and Jeffrey Klopatek. 1982. A regional approach to prediction of distribution and abundance of animal species. Final Report for Interagency Agreement (IAG 40-1105-80), ORNL, Environmental Sciences Division and USDA Forest Service, Rocky Mountain Forest and Range Experiment Station, 72 p + appendix. Mimeo.*

descriptor variables estimated exogenously in area projection, and other resource inventory projection.

Econometric area projection models that include the economic and social assumptions for forestland, rangeland, and cropland are being developed with the vegetation type and structure variables given in table 1 (Alig and Knight 1983). Such area projection models estimate likely future acreages through assumptions of how prices of market resources, population levels, etc., will change in the future; they are based on historical relationships between these variables and land use. Wildlife inventory projections developed in conjunction with area projections are restricted to the limits of their relationship in historical data. Scenarios that might be of interest, but are outside past experience, are not analyzable.

To perform analyses estimating multiple resource production, it is necessary that the analyses of all renewable resources be based on the same units of land and the same set of potential management actions (Joyce 1983). There is currently no standardized multiresource definition of management actions from which individual resource production responses could be estimated. Few production response relationships between management actions and wildlife and fish resources have been quantified, and fewer still have been quantified for multiple resources (which include wildlife and fish). Fortunately, in a specific ecological situation, only a limited number of different management actions are typically carried out; this makes the framework less complex.

Timber inventory projection models provide a means by which wildlife populations primarily associated with forestland can be projected. Such inventory projection models, which incorporate land area and timber stand characteristics, can be linked to wildlife models that contain the same management intensification variables. Like the area projection models, this approach is restricted by the relationships available in historical data.

Opportunities for Improving the Future Renewable Resource Situation

To discuss this third technical component for an assessment of wildife and fish, it is necessary to define the economic concept of technical efficiency (e.g., Henderson and Quandt 1971). A production system can be said to be in a technically efficient state when, given the inputs available, no more of any output can be produced without a resultant reduction in the production of some other output or outputs. Production tradeoffs can be defined only in the context of technical efficiency, since in the absence of such efficiency, more of any given output can be produced with no tradeoff in other outputs. Also, technical efficiency is an important concept in discussing "opportunities to improve the renewable resource situation" because most of these opportunities involve a movement towards more technically efficient ways to manage renewable resources.

To analyze technically efficient production tradeoffs or potential improvements in technical efficiency, some means is necessary to sort out all the inefficient ways of managing renewable resources from the more efficient ways. One very popular approach to doing this is linear programming (LP). Again, its purpose in the context of this report is to sort through a large number of management actions that might be applied to arrive at a management configuration (model solution) that maximizes or minimizes some objective function, such as maximum output, minimum cost, and maximum present net worth.

A number of papers describe mathematical programming procedures that are appropriate for generating multiresource production possibilities (e.g., D'Aquino 1974, Ashton et al. 1980, Kent 1980).[5] In the USDA Forest Service, a model called FORPLAN (Johnson et al. 1980)[6] is used for this purpose at the National Forest level. Each alternative opportunity generated simply includes the vector of multiresource outputs that can be produced at an associated joint cost, and the economic benefits associated with those outputs. Recognizing that the Forest Service is a multilevel agency (Forest, Region, and National levels), planning future opportunities necessarily occurs at all three levels. Wong (1980) and Hof et al. (1983) propose a multilevel optimization system with local, regional, and national level models.

Figure 1 depicts the linear programming matrix of a very simple version of a national model. A regional model would be structured similarly, with forests replacing the regions in figure 1. In this example, only two regions, two alternatives, three products, and one time period are included. Expansion beyond the dimensions of this simple example is straightforward. In figure 1, X_1 through X_4 are 0-1 variables representing selection or rejection of an alternative output vector (A_{ij}) with associated joint cost (F_i; $i = 1, 4$) for a given region. For example, X_1 represents selection or rejection of the entire output vector $A_{1,1}$; $A_{2,1}$; $A_{3,1}$ in Region 1. Rows 5 through 7 set national "targets" on the 3 outputs (T, W, F). Row 4 places a budget constraint on the selection of alternatives, and row 8 is the objective function to be maximized. All of the matrix below the objective function row constrains the X_1 through X_4 so that each of them is between 0 and 1, and so that only 1 alternative can be selected for each region (ignoring non-integer solutions).

The principal advantage of a multilevel optimization such as this is that the detail and high resolution of local-level analyses are preserved, but some national discretionary choice is still allowed. The implied national model reflects a great deal of detailed production analysis, but is of very workable size and complexity. Also, any national model solution is automatically disaggregatable to (and consistent with) local management plans. The principal shortcoming of a multilevel optimization approach is that limiting the national analysis to a finite number of discrete choices may overlook desirable options and thus lead to suboptimization.

[5]*Kent, Brian M. 1980. Introduction to linear programming. 63 p. Department of Agriculture, Land Management Planning, Systems Application Unit, Fort Collins, Colo.*

[6]*Johnson K. Norman, Daniel B. Jones, and Brian M. Kent. 1980. Forest planning model (FORPLAN) user's guide and operations manual draft. 258 p. U.S. Department of Agriculture, Land Management Planning, Fort Collins, Colo.*

	Region 1		Region 2		Outputs				
	X_1	X_2	X_3	X_4	T	W	F	Type	RHS
Timber	$A_{1,1}$	$A_{1,2}$	$A_{1,3}$	$A_{1,4}$	-1			=	$0 = K_1$
Wildlife	$A_{2,1}$	$A_{2,2}$	$A_{2,3}$	$A_{2,4}$		-1		=	$0 = K_2$
Forage	$A_{3,1}$	$A_{3,2}$	$A_{3,3}$	$A_{3,4}$			-1	=	$0 = K_3$
Budget	C_1	C_2	C_3	C_4				$\leq$	K_4
					1			$\geq$	K_5
						1		$\geq$	K_6
							1	$\geq$	K_7
Obj. Fun.	$-F_1$	$-F_2$	$-F_3$	$-F_4$	F_5	F_6	F_7	–	MAX
0 – 1 Model	1	1						=	1
Constraints			1	1				=	1

Figure 1.—A simple national model, where the X_1 through X_4 are 0-1 variables representing selection or rejection of an output vector $A_{i,1}$ through $A_{i,4}$ (i = 1,3), respectively. The F_i are the objective function coefficients, and K_1 through K_7 are right-hand sides (RHS).

Conclusion

National assessments of wildlife and fish as carried out by the USDA Forest Service are integral parts of national resource planning. In addition to the traditional analyses of the status and condition of wildlife and fish resources, national assessments should project inventories and use and analyze opportunities and implications for changing the future resource situation.

The technical components for national assessments discussed in this report are intended to provide guidance to wildlife biologists on the data needs and analysis procedures useful in developing the mandated periodic reports to Congress. Consistent information is highly desirable for the relatively small number of data items used in national assessments. National assessments are one means of providing comprehensive reports about the wildlife and fish resources and of examining the production tradeoffs that can be made in the future regarding the national resources produced on the nation's forestland and rangeland.

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Keywords: National assessments, national appraisals, renewable resource inventories, resource use projections, opportunities analysis, trade-off analysis

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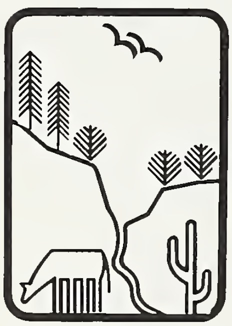

Southwest

Great Plains

The Rocky Mountain Station is one of eight regional experiment stations, plus the Forest Products Laboratory and the Washington Office Staff, that make up the Forest Service research organization.

RESEARCH FOCUS

Research programs at the Rocky Mountain Station are coordinated with area universities and with other institutions. Many studies are conducted on a cooperative basis to accelerate solutions to problems involving range, water, wildlife and fish habitat, human and community development, timber, recreation, protection, and multiresource evaluation.

RESEARCH LOCATIONS

Research Work Units of the Rocky Mountain Station are operated in cooperation with universities in the following cities:

Albuquerque, New Mexico
Flagstaff, Arizona
Fort Collins, Colorado*
Laramie, Wyoming
Lincoln, Nebraska
Rapid City, South Dakota
Tempe, Arizona

*Station Headquarters: 240 W. Prospect St., Fort Collins, CO 80526